Perceptual and Motor Skills, 1985, 60, 416-418. © Perceptual and Motor Skills 1985

GEOPHYSICAL VARIABLES AND BEHAVIOR: XXV. ALTERATIONS IN MEMORY FOR A NARRATIVE FOLLOWING APPLICATION OF THETA FREQUENCY ELECTROMAGNETIC FIELDS[1]

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Summary.—Subjects were asked to listen to a 3-min. narrative. During Min. 1, 2, or 3 of the narrative, subjects were exposed for 60 sec. to either 5-Hz or 20-Hz electromagnetic fields or to a sham field condition. The fields were generated by commercial devices and applied externally to the side of the head at the level of the temporal lobe. The transcript of each subject's version of the narrative was evaluated by discourse analyses for the numbers of direct recalls or of inferences for each of the three segments. Subjects who had received the 5-Hz fields during Min. 1 and 2 of the narrative displayed twice as many inferences for the material that had been presented during Min. 1 only compared to the 20-Hz groups who did not differ from the sham-field subjects. We hypothesize that there are small alterations in the processing of complex series of verbal stimuli by these weak, theta frequency electromagnetic fields. They might not affect the amount of recall but they may influence the details of recall.

Ojemann (6) has reported several forms of transient dysphasia, such as anomia, during simultaneous presentation of a verbal stimulus and the direct stimulation of the temporal lobe by surgical techniques. He noted that stimulation of "silent cortex" can disrupt an ongoing language task. This behavioral disruption disappears when the stimulation ceases (assuming that the current remains below the threshold for after-discharges). These optimal currents and frequencies disrupt the consolidation (or retrieval) process when they are localized to specific functional portions ($\sim$ 5 mm^2) of the temporal cortex.

We suspected that externally applied extremely low frequency (ELF; 7) electromagnetic fields (EM) might also influence the language processing (consolidation) of a complex narrative. Although the electric currents induced by these fields would be much less localized, we assumed they might enhance activity within the more labile cortical columns of the temporal lobe (1, 3). Whereas the small energies involved with experimentally admissible ELF-EM fields might not evoke blatant anomia or alter the memory for the themes of a story, we suspected that there might be more frequent substitutions of the details. The substitutions would occur as increases in the numbers of inferences relative to the numbers of direct recalls. For example, the direct recall of "Jill jumped over a crack in the sidewalk" is the phrase verbatim. An inference series would be "Jill *skipped* over the crack in the *pavement*."

A total of 32 first-year psychology students (16 males and 16 females) whose ages ranged from 18 to 24 yr. volunteered as subjects; each received 2% bonus marks that were added to the final grade. Over a 4-wk. period, each subject was tested singly (and alone) in an acoustic chamber (5). Each subject wore a modified, plastic motorcycle

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helmet to which a Relaxit (5) was attached (on either the left or right side at the level of the temporal lobe). One of three Relaxits were used: 5 Hz, 20 Hz, or sham (source disconnected). The 5-Hz and 20-Hz devices generated magnetic fields ($\leq$ 1 gauss) whose characteristics have been reported elsewhere (5).

After the experimenter had left the chamber and closed the door, the experiment began. Each subject had been told to listen for instructions. The same tape[2] was played to the subjects. They were told that they were going to hear a story and that they would be asked to tell the story in their own words upon its completion. The story was a 3-min. narrative called "The Dinosaur Egg Hunt"; its syntactic structure had been segmented and standardized by Frederickson (2).[3] During Min. 1, 2, or 3 of the narrative, the subjects received either the 5-Hz, 20-Hz, or no-field condition. The field and sham devices were turned on and off from outside of the chamber and verified by the presence or absence of their signals on an external monitor. At the end of the story, the narrator asked the subjects to retell the story; each version was taped.

The typed transcripts of each story were analyzed frame by frame according to the method of Frederickson (2) for the total numbers of recalls and inferences for the first, second, or third part of the narrative. The data were analyzed by five-way analyses of variance with two factors repeated for the field-exposed subjects only. The first level of the repeated measures was the three segments (min.) while the second was the total numbers of recalls or inferences (per min.). The three independent variables were frequency (5- vs 20-Hz), hemisphere and gender. For comparison, *a posteriori* analyses were completed between the 24 field-exposed subjects and the eight reference (sham field) subjects. All analyses were completed by BMD-P2V (repeated measures) and SPSS (for verification) on a DEC2020 System computer.

The primary analyses demonstrated no statistically significant main effects; however there was a statistically significant ($p < .01$) main effect for repeated measures ($F = 7.85$, $df = 2/24$). All subjects had fewer inferences (4.2 ± 2.8) and recalls (5.3 ± 3.6) of Min. 2 of the narrative compared to Min. 1 (7.9 ± 3.8; 7.8 ± 4.9) or Min. 3 (6.1 ± 3.7; 8.6 ± 5.0). A statistically significant ($p < .05$) interaction ($F = 3.97$, $df = 2/24$) occurred between the minute of the field presentation, the form (recall vs inference) and the field frequency. *A posteriori* analyses indicated that the group who had received the 5-Hz field during either Min. 1 or 2 displayed significantly ($F = 7.59$, $df = 1/12$, $p < .01$; $\omega^2 = 35\%$) more inferences (10.5 ± 3.3; 12.8 ± 4.6, respectively) for their versions of Min. 1 only than those who received 20-Hz during this time (7.7 ± 2.2; 6.0 ± 4.2) or those who had received during Min. 3 either the 5-Hz (8.0 ± 2.1) or 20-Hz (5.8 ± 2.1) fields. Neither the 5-Hz nor the 20-Hz fields significantly influenced either recall or inferences for the same subjects' versions of Min. 2 and 3. Similarly, the numbers of recalls and inferences of Min. 3 for those subjects who received the 5-Hz fields during Min. 1 or 2 did not differ from any of the 20-Hz groups. The use of relative measures (e.g., number of inferences per segment divided by the total for each subject), to attenuate possible effects from total amounts of material, did not change the statistical significance of the results.

The effect of the 5-Hz field upon the information that was presented during the first minute was evident when the three groups from each field condition were combined. The means and standard deviations for the total numbers of direct recalls for the 5-Hz (8.5 ± 5.6), 20-Hz (6.7 ± 3.3), and control (8.2 ± 5.1) groups were not statistically significant. On the other hand, the numbers of inferences for each condition were: 5-Hz (10.4 ± 3.7), 20-Hz (6.5 ± 3.0), and reference (6.1 ± 3.5); a conservative *a posteriori*

[2]Thanks to Mr. Richard Malo of CHNO for his reading and recording of the narrative.
[3]Thanks to Dr. Gaye Musgrave for assistance and for the introduction to discourse analyses.

test set at $p < .01$ indicated that only the 5-Hz group displayed significantly more inferences. These results indicate that relatively weak ELF fields may alter the memory of complex sequences such as a narrative. Interestingly, the 5-Hz but not 9-Hz or sham fields have been shown to enhance reports of relaxation in subjects who were tested under double-blind conditions (5). The fewer over-all references to the middle portion of the narrative relative to the beginning and end are commensurate with the well-known primary and recency effects (4).

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Accepted February 2, 1985.